AC 2007-649: A STUDENT PROJECT: DEVELOPING LABVIEW DRIVERS FOR A MEASUREMENT BRIDGE

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14. ABSTRACT
A measurement bridge to calibrate inductive voltage dividers has been developed at the National Institute of Standards and Technology [1-3]. The bridge is based on the straddling technique and performs self-calibration of decade inductive voltage dividers. It has been driven by a programmable dual-channel source and its output has been monitored with a signal analyzer. A student project was formulated to develop LabView programs in order to fully replace the existing equipment. This paper will describe the implementation of the LabView drivers for the straddling bridge.

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A Student Project: Developing LabView Drivers for a Measurement Bridge

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Abstract - A measurement bridge to calibrate inductive voltage dividers has been developed at the National Institute of Standards and Technology [1-3]. The bridge is based on the straddling technique and performs self-calibration of decade inductive voltage dividers. It has been driven by a programmable dual-channel source and its output has been monitored with a signal analyzer.

A student project was formulated to develop LabView programs in order to fully replace the existing equipment. This paper will describe the implementation of the LabView drivers for the straddling bridge.

I. INTRODUCTION

The original bridge was designed and implemented in 2003. It consists of a comparator and binary inductive voltage divider system [1-3]. The measurement procedure is semiautonomous. LabView is used to control the instrumentation and the user configures the device under the test conditions.

Since a fast iterative measurement procedure is required for balancing the bridge, a decision has been made to replace the voltage supply with a new digital data acquisition board with analog-to-digital and digital-to-analog capabilities.

The bridge supply signals require accurate amplitude and frequency setting, as well as phase shift adjustment between the in-phase and quadrature signals (signals that are 90 degrees apart). Also, the bridge balance detection signals comparison requires accurate voltage measurements.

Two source signals are provided to the system: a sine wave, A, and the sine wave, B, phase shifted by ninety degrees compared to A. These are the supply signals, in phase and quadrature.

The signal analyzer is used to measure the difference in phase between the input and output signal across the test component.

II. HARDWARE CONFIGURATION

The Measurement Computing PCI-DAS6052 card is an analog-to-digital (A/D) and digital-to analog (D/A) converter card for use in microcomputers. It was selected for the ability to sample at 333000 samples/second (333kHz). The operating range desired for the bridge system was to range from 50Hz to 20kHz.

Analog signals are measured as a real electrical voltage quantities. Analog to digital occurs when the card samples the voltage at a given terminal and uses internal circuitry to estimate a digital binary value that coresponds to the physical value. In contrast, digital to analog conversion is achieved by interpreting a binary value and using digital logic gates to output a physical approximation of the voltage desired. The precision to which A/D and D/A conversion can be achieved is referred to as a card's resolution. The resolution of the PCI-DAS6052 is discussed in section III.

Although the PCI-DAS6052 was capable of simultaneous generation of two independent output signals at maximum sample frequency, input sample frequency was shared between all input channels enabled. Because it was desired to simultaneously sample four analog signals, the maximum achievable input sample rate was 83.25kHz.

A/D and D/A operations were synchronized by connecting the D/A update signal to the A/D clock trigger.

III. EFFECTIVENESS OF SIMULATING WITH LABVIEW

The maximum theoretical input sampling frequency for four simultaneous independent signals was 83.25kHz, as discussed previously. If a sample rate of 333kHz was used by the D/A converter, stuttering appeared in the output signals. Therefore, the max sample rate was limited to some value marginally less than 333kHz.

For example, given a desired output signal of 20kHz, a 333kHz output sample rate would have resulted in $\frac{333\text{kHz}}{20\text{kHz}} = 16.65 \frac{\text{samples}}{\text{period}}$. This means that the starting point along the sine wave would shift forward slightly, ie. waves would begin at $y(\omega t + n\pi + a)$, where a represents the 0.65 sample shift, instead of $y(\omega t + n\pi)$. The result of this effect on the input is that instead of sampling a single discrete set of 16 samples, a multitude of samples along the sine wave is measured. Although digital signal analysis could have been used to neutralize the stuttering, the loss of a marginal amount of sampling resolution was deemed acceptable in order to better synchronize input and output.

To achieve an integer number of samples per period, a 20kHz signal was, for example, sampled at 16 samples/second, or 320kHz. This is the resolution of the generated output at 20 kHz. If 20 kHz is input signal it was sampled at 4 samples/per period, or 80 kHz. This value was still greater than the Nyquist rate of 40kHz. Also, it was determined that 16 output samples/period would be sufficient to operate the system's hardware, while 4 input samples/period would be sufficient to precisely calculate the input amplitude and phase angle. We therefore conclude that the PCI-DAS6052 is capable of operating within the target frequency range.

The PCI-DAS6052 is capable of 16 bits of voltage resolution. The voltage range $\pm$ 10V was used for this application. Each voltage step for this range was equivalent to a change of about $\frac{20\text{V}}{2^{16}} = \frac{20\text{V}}{65536} = 305\mu\text{V}$. However, experimental error appeared to be significantly more than this value and was likely attributed to electrical noise. Proper statistical analysis of data would have to be performed to confirm this observation. With signal processing, the amplitude and phase of two input signals were measured consistently to five significant digits.

IV. Program Design

The program was written in LabView 7.1. Measurement Computing's proprietary software, *Instacal*, was used to configure the PCI-DAS6052. Two separate virtual instruments were created to reduce software-induced interference. When both input and output operations were implemented in one virtual instrument, the delay incurred when the program responded to user input on one device seemed to interfere with the function of the other. Although the structure of LabView should have prevented this phenomenon, it was decided that modularizing the two components of the program would at least simplify debugging.

The following is a simplified explanation of the program flow. Figures 1, 2, 3 and 4 may be helpful for clarification. Although Measurement Computing claims that the PCI-DAS6052 supports built-in National Instruments sub-programs, or sub-virtual instruments, or subVI's, they only provide technical support for their proprietary software. For that reason, Measurement Computing subVI's were used to implement the driver.

The two-channel sine generator takes the desired signal amplitude, phase shift, and frequency as inputs. These are saved for use during input. Mult4Convert.vi calculates the appropriate sample rate to avoid aliasing. The proper sampling rate, amplitude, and frequency are used inside a loop that generates an array of samples corresponding to the desired sine wave. A parallel loop generates an identical signal phase-shifted to the desired amount. The arrays then pass through several signal processing SubVI's that truncate the arrays to equal sizes and convert raw values into English units. These values can then be interpreted by Measurement Computing's AOutScBg.vi subVI, which continuously generates output samples in the background until the user requests an interrupt, which stops the program.

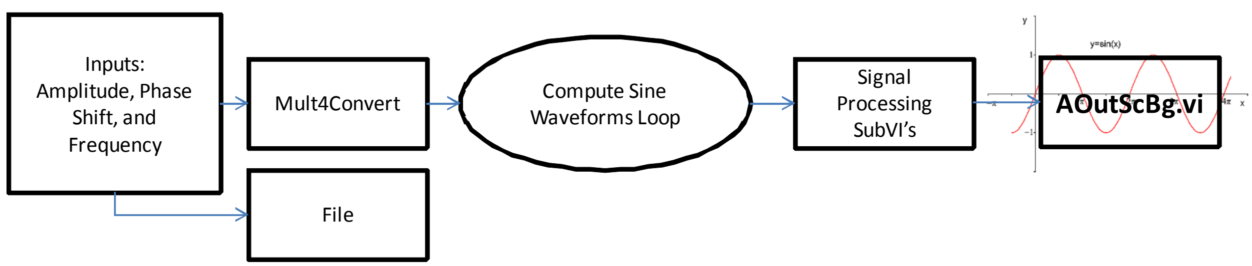

Figure 1. Two-channel sine generator program flow.

The four-channel analog-to-digital converter input instrument largely depends on Measurement Computing's AInScBg.vi, which continuously samples the desired input channels until the user requests an interrupt, stopping the program. A few modifications are made to the raw data, which is then transferred to InputTrigger.vi, which calculates the first time the waveform on Channel 0 crosses the x-axis with a rising slope. The value this subVI generates is then used as the first plotted value for display, resulting in a steady image of the sampled signals that always starts at $y(0) = 0$ and $y'(0) > 0$ for Channel 0.

The phase and amplitude calculation is based on National Instrument's sinfit3p_nharms.vi. Based on estimates for signal frequency and sample rate, it outputs the measured amplitude and phase of a signal based on a reference. This subVI takes inputs from the two-channel sine generator. Phase, amplitude, and output from the four-channel grapher are displayed on the front panel (see Figures 5 and 6).

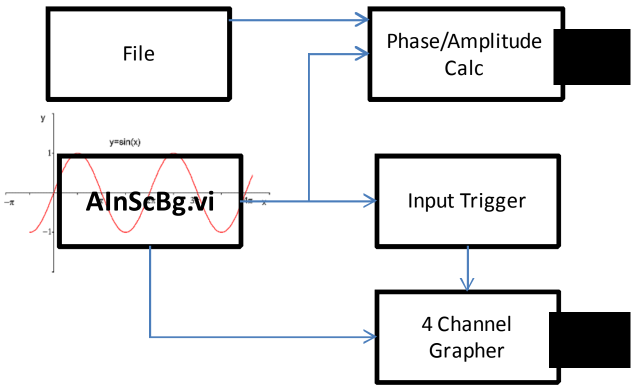

Figure 2. Four channel analog-to-digital converter program flow.

V. CONCLUSION

At the time of this writing, the Labview drivers for the PCI-DAS6052 have yet to be integrated into the inductive voltage divider. This should be done and comparisons should be made between the automated system and the original hardware.

The precision of the Labview results needs to be increased before the system can be effective. It is unclear whether the error measured when comparing the two output signals will be significant after passing through the bridge.

The scope and scale of the project described herein were largely decided by the student. Armed with a end goal in mind, the student was expected to learn any prerequisite material and seek help outside sources. This attribute of the project gave the student a chance to experience the difficulties of research when no answers are available from an omniscient professor or mentor. The downfall of this independence is that work progressed slowly and many coding ideas were explored, found to be inadequate, and discarded. The end result of this project was that a well-planned and detailed LabView driver was successfully created, but integration into the rest of the system was not achieved because of lack of time.

References:

[1] S. Avramov-Zamurovic, B. Waltrip, K. Stricklett, and A. Koffman, "A Balancing Algorithm for system with correlated injections" IEEE IMTC Proc., Vail, Colorado, 2003.

[2] B. Waltrip, A. Koffman, S. Avramov-Zamurovic: "The Design and Self-Calibration of Inductive Voltage Dividers for an Automated Impedance Scaling Bridge", IEEE IMTC Proc. Anchorage, Alaska, 2002.

[3] B. C. Waltrip S. Avramov-Zamurovic and A. D. Koffman "A Capacitance Measurement System Using an IVD Bridge", NCSL Workshop and Symposium Proc., Washington DC, 2001.

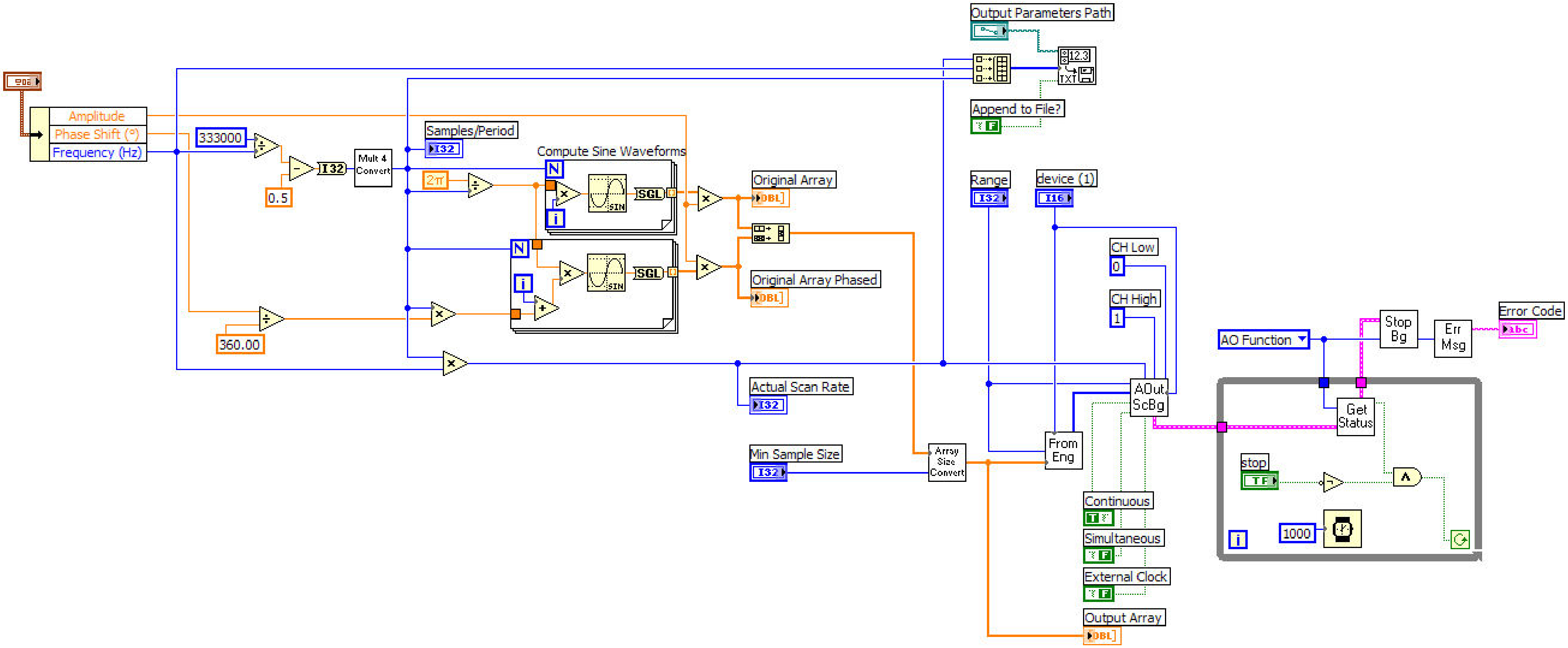

Figure 3. Two-channel sine generator block diagram.

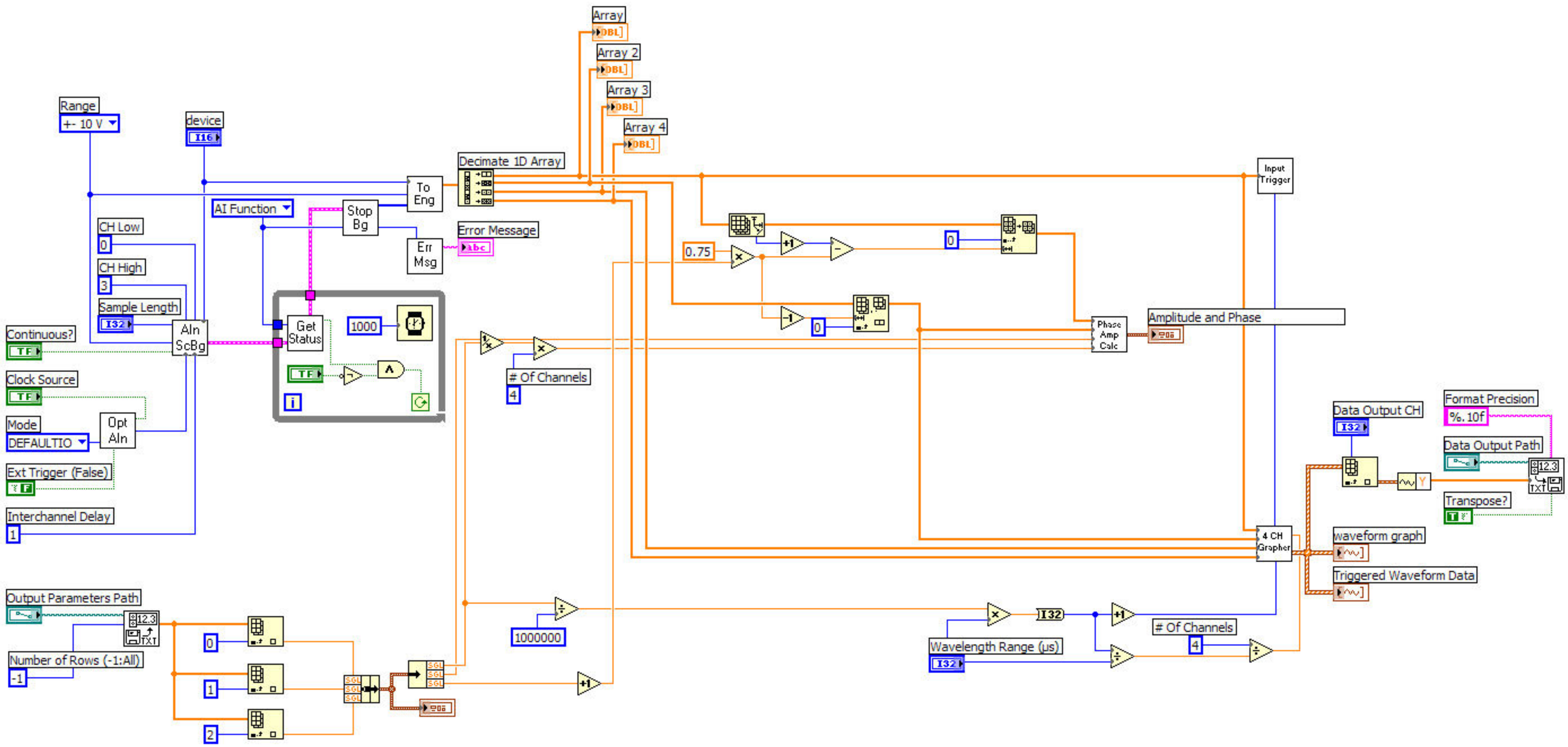

Figure 4. Four channel analog-to-digital converter block diagram.

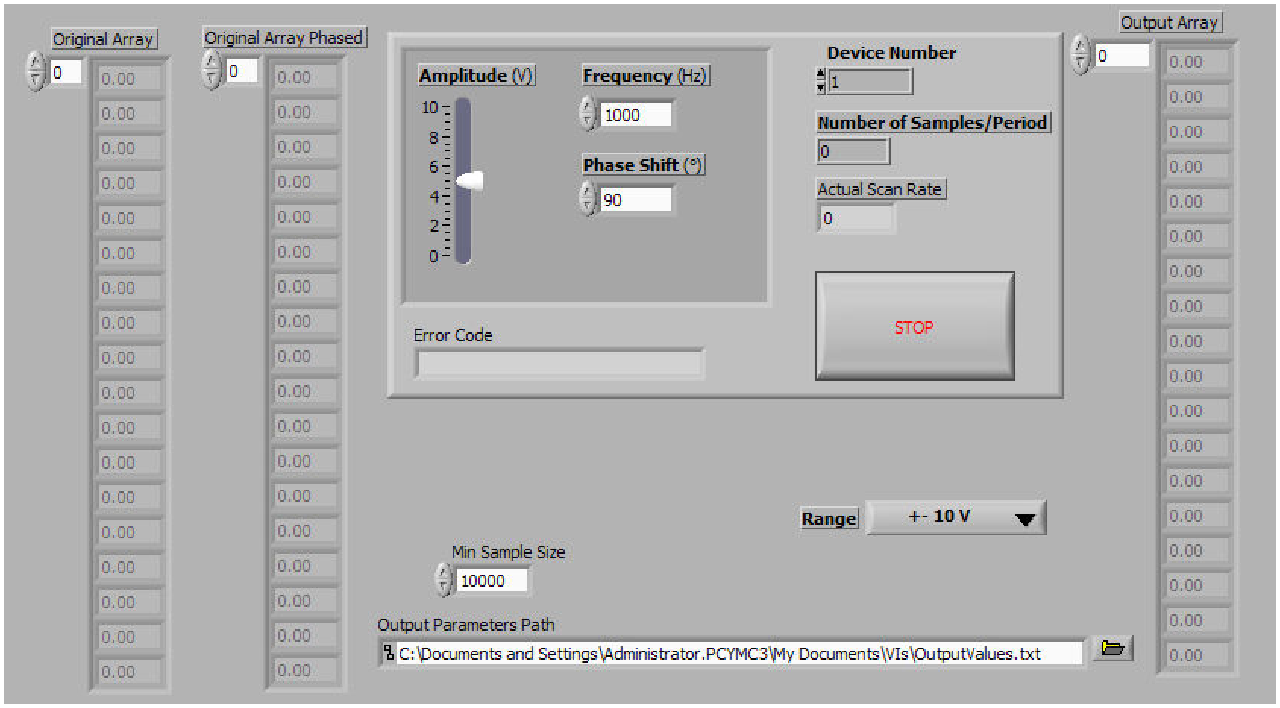

Figure 5. Two-channel sine generator front panel.

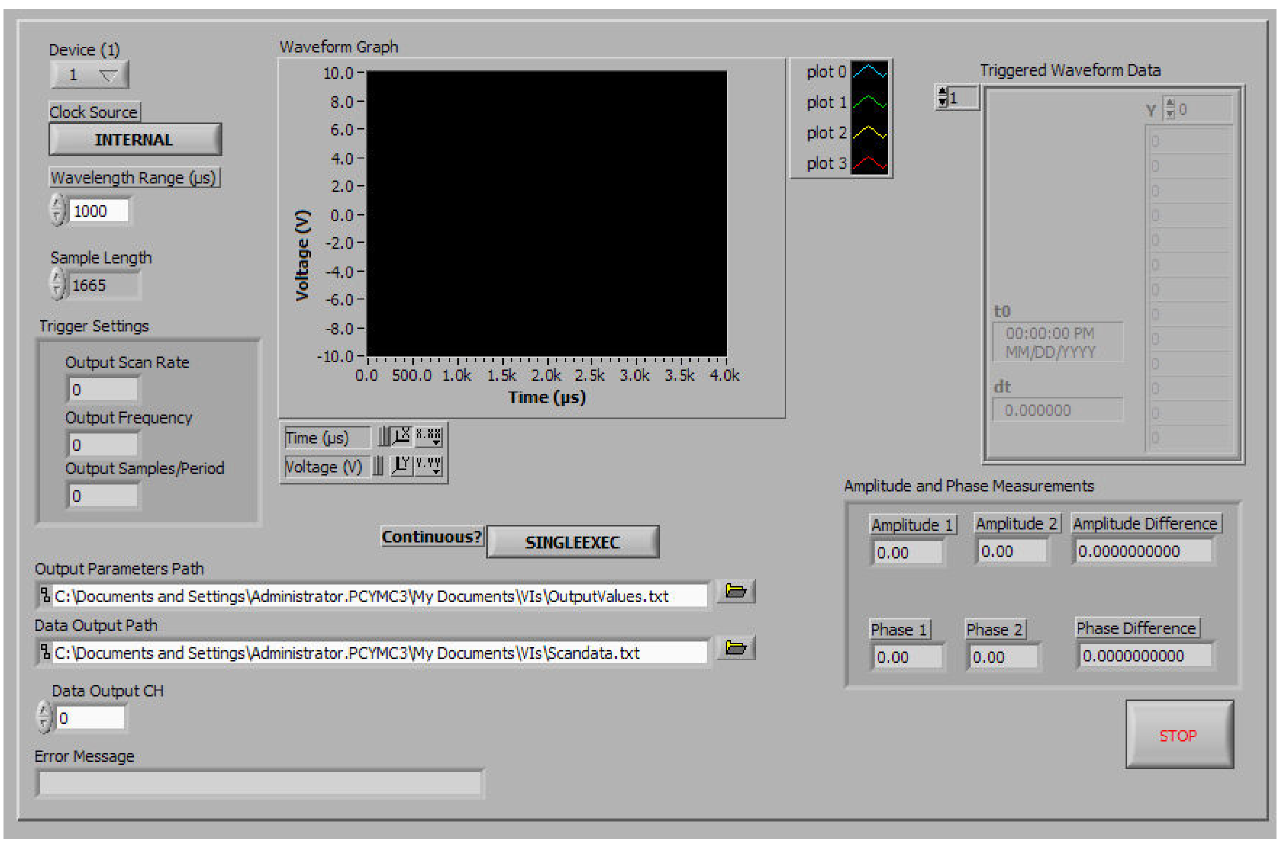

Figure 6. Four channel analog-to-digital converter front panel.